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ABSTRACT: The empirical relationship among corn prices, ethanol production, and government subsidies is investigated. An econometric model of the demand for corn is proposed and then estimated with two stage least squares. The estimated demand function is used to evaluate the effects of changes in ethanol markets on domestic corn markets. The results show that an increase in the price of ethanol increases both the equilibrium quantity demanded and price of corn. Agricultural subsidies are then brought under question in light of econometric evidence and coupled with current trends in the ethanol and corn industries.

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INTRODUCTION

By analyzing the relationships among agricultural subsidies, ethanol markets, and corn markets, this research contributes to the existing agricultural economics literature. The study brings the three topics together in a framework that allows for dynamic relationships and interdependencies among key variables. Corn and ethanol production are naturally interdependent because corn is the main feedstock used to produce ethanol, and likewise ethanol is becoming a significant determinant in farmers' production decisions regarding corn. Government support programs are then brought into question due to the significant number of tax dollars that feed the different subsidies, as juxtaposed with the increased demand and thus profitability of the corn industry.

A specific case in which ethanol acts as an exogenous shifter in the demand for corn allows for the effects of ethanol production on corn prices to be analyzed. The use of ethanol has come under heavy debate where strong opinions have formed on both fronts. The purpose of this paper, therefore, is to shed light on ethanol and corn markets in order to better understand the place of agricultural subsides.

THE LITERATURE

In the field of agricultural economics, comprehensive assessments of corn markets, ethanol markets, and agricultural subsidies are readily found. Some of the more pertinent studies are outlined in the following sections to provide a basis for the present paper. The discussion of prior research and literature will be subdivided into three categories: agricultural subsidies, ethanol markets, and corn markets.

2.1 Agricultural Subsidies

Over the past ten years total agricultural subsidies in the United States ranged between $12 and $36 billion per year with an average of just over $23 billion per year (US OMB 58-60). The first agricultural subsidy program was the 1862 Morrill Act, which established the land-grant colleges. During the 1930s, subsidies began to take hold because of the Agricultural Adjustment Act and the New Deal, as did commodity price supports and production controls, marketing orders to limit competition, import barriers, and crop insurance (Edwards 2008). Many changes have been made to these programs over the years, but the fundamental central planning aspects have not. Uncertainty in the production of some agricultural commodities, frequently related to the unpredictability of nature or to human-generated interruptions either of supplies of imported food or of inputs to domestic production, is often the reasoning given for subsidy programs (Legg 2003).

Each time reforms to these programs are presented to Congress, they are either rejected or result in an increase, rather than a decrease, in subsidy payments. Currently, there are eight major types of farm subsidies: direct payments, marketing loans, countercyclical payments, conservation subsidies, insurance, disaster aid, export subsidies, and agricultural research and statistics. Wilfred Legg (2003), a prominent figure on agricultural and environmental policy issues and the current Head of Policies and Environment Division in the OECD Agricultural Directorate, goes into great detail in his presidential address, outlining both the definition and the measurement of agricultural subsidies.[1] Generally speaking, subsidies inherently create winners and losers; sectoral policies coupled with electoral cycles build a domestic constituency that supports the continuation among the few winners who gain a lot but rarely among the losers who each lose a little (Legg 2003). Agricultural subsidies have become an important part of corn farmers' production decisions and therefore must be included in any discussion of the economics of agricultural markets.

2.2 Ethanol Markets

Ethanol has seen explosive growth in popularity and production in recent years. Bio-based fuels such as ethanol provide potential solutions to urban air quality, global warming, and excessive dependence on imported oil, as well an economic solution to high crude oil costs (Ferris and Joshi 2004). Policy incentives exist at both federal and state levels that further support the growth of renewable fuels. An example of these is the Clean Air Act of 1990, which imposed mandatory oxygenate levels upon gasoline in areas with air quality issues. Also, the Energy Policy Act of 2005 introduced the Renewable Fuel Standard, which requires US fuel production to include a minimum amount of renewable fuels each year; the program starts at four billion gallons in 2006 and reaches a mandatory minimum of 7.5 billion gallons in 2012 (Tokgoz and Elobeid 2008). One way to meet these regulations and to reduce emissions is to blend gasoline with ethanol, accounting for about 79% of the US oxygenate supply in 2006 (Energy Information Administration 2008). In the US, the most common ethanol blend with gasoline is 10% (E-10), which can be used in any standard unleaded vehicle. Ethanol is also produced in an 85% blend (E-85) that can only be used in flex-fuel vehicles (FFVs), which run on gasoline, ethanol, or any combination of the two.

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Ferris and Joshi (2004) used an empirical model to examine the determinants of increased ethanol production and its subsequent impact on the agricultural industry. To determine these impacts, the authors proposed five events that could contribute to increased ethanol production, and then examined their cumulative effects in different combinations. These events are as follows:

1. Fourteen state or Federal ban on MTBE, a substitute to ethanol in gasoline blends.
2. Congress passing the Federal Renewable Fuel Standard.
3. Increased use of ethanol as a blending agent due to high gasoline prices that tend to make ethanol a cost-effective octane enhancer.
4. Supreme Court ruling to enact revised national air quality standards for 8-hour ozone concentrations.
5. United States Department of Agriculture (USDA)'s Commodity Credit Corporation (CCC) providing incentive programs for bioenergy production.

Through the use of a multi-sector econometric model called AGMOD that contains over 400 equations and more than 700 variables, the authors produced quantitative results concerning both ethanol and corn markets. Ferris and Joshi (2004) assumed that corn will be used as feedstock for ethanol production, resulting in ethanol production projections for 2010 that ranged from 3,250 million gallons to 4,670 million gallons. The proportion of total corn production used in ethanol production ranged from 9.5% to 14.8% in 2010. The price received by corn producers increased nearly 30% from 2003 to 2010. [2] The final conclusions made by Ferris and Joshi (2004) posited:

1. Corn ethanol demand is likely to increase rapidly due to proposed changes in energy and environmental policies.
2. Agricultural commodity prices will increase more sharply in the short run, followed by moderate increases due to expanded acreage under grain production.
3. Increased use of ethanol fuel is likely to be beneficial to farmers, improve air quality and contribute to energy security by marginally reducing dependence on foreign oil.

These results point towards an increasing use of ethanol as a blending agent with gasoline. This increased use would in turn have ripple effects in the agricultural sector, specifically to corn.

Another study on ethanol and its effects on agriculture, by Tokgoz and Elobeid (2006), modeled the link between ethanol, energy, and crop markets. The authors systematically decompose the factors affecting the international ethanol market and then proceed to contrast the US and Brazilian ethanol markets. One fundamental difference between the two markets is the type of inputs used. In Brazil the major feedstock for ethanol production is sugarcane, as opposed to corn in the US. Both feedstocks face competition in the intermediate input market. In the US, ethanol competes with livestock industries that use corn as feed. In Brazil, however, sugarcane used to produce ethanol could otherwise be used in the production of sugar rather than ethanol. Tokgoz and Elobeid (2006) examine the use of ethanol as a substitute for gasoline and also as a complement in the production of gasoline.

The results provided by Tokoz and Elobeid (2006) showed that a 20% increase in gasoline prices in the US would result in a 4% decline in composite gasoline consumption. At the same time the share of fuel ethanol in composite gasoline consumption increased by 2.5% due to substitution. The total ethanol consumption, after the increase of gasoline prices, declined by 1.5% because the increase use of ethanol as a blending agent was less than the decrease use of blended fuel. The net effect on corn demand predicted by the authors was a 0.6% increase in consumption. These results were built upon the assumption that the number of FFVs in the US is limited in the short run. In the long run, with an increase in the use of flex-fuel vehicles, substitution of ethanol for gasoline increases and thus higher gasoline prices will lead to increased ethanol consumption. Conclusions reached in the study depended upon the composition of the domestic vehicle fleet. The proportion of FFVs determines whether ethanol acts as a substitute for or complement of gasoline.

2.3 Corn Markets

Several papers addressing estimates of corn demand will be used to construct the model utilized in this research. One of the more recent papers regarding corn markets that will be used to construct the hypotheses of the current study is that by John Marsh (2007). He examined the farm-level relationships that exist among the corn,

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livestock, and poultry markets by assessing interdependencies on inputs, demands, and supplies of each commodity. The paper developed an econometric model that integrates four sectors through mutual dependency of structural demands and supplies. These factors are used to estimate cross-sector impacts of changes in corn loan rates, corn export demand, and fertilizer costs on the demand for and supply of livestock and poultry, or inversely, the effect of livestock and poultry meat demand on the demand and supply of feed corn.

The focus upon farm-level production reflects different degrees of vertical integration/coordination in the sectors. For example, the feeder pig market is not separated due to an industry dominated by integrated farrow-to-finish operations. The sectors defined in the model are: feeder cattle, slaughter cattle, slaughter hogs, wholesale broilers, and corn production. The supply and demand curves are theoretically based on first-order necessary conditions of firm profit maximization. First principles of the optimization problem give input demands as a function of own input prices, substitute input prices, output prices, and technology. Output supply functions depend upon own prices, substitute prices in production, input prices, and technology. For the corn sector, Marsh presented the following equations, which are summarized in Table 2.3.1:

1. $Q^S_{CN} = \Upsilon_1(P^S_{CN}, P_{LN}, P_{FT}, P_{SY}, D_P, T) + \mu_1$ (supply)
2. $Q^D_{CN} = \Upsilon_2(P^D_{CN}, P_E, P_{SS}, P_{SH}, P_{EW}, P_{SG}, T) + \mu_2$ (demand)
3. $Q^S_{CN} = Q^D_{CN}$ (quantity market clearing)
4. $P^D_{CN} = P^S_{CN}$ (price market clearing)

Table 2.3.1 *Marsh's Supply and Demand Variables*

1. Q_{CN}	Quantity corn produced (billions of bushels)
2. P_{CN}	Price of No.2 yellow corn – Central US ($/ bushel)
3. P_{SS}	Price of Choice yield 2-4 1,100-1,300 lbs steers, Nebraska Direct ($/cwt)
4. P_{SH}	Price of Nos.1-3 barrows and gilts – Iowa/ Southern Minnesota ($/cwt)
5. P_{BW}	Wholesale price of broilers (¢/lbs)
6. P_{LN}	USDA nonrecourse corn loan rate ($/bushel)
7. P_E	Export price of yellow corn ($/bushel)
8. P_{SG}	Price of No. 1 yellow sorghum – Chicago ($/bushel)
9. P_{FT}	Price of nitrogen fertilizer ($/ton)
10. D_P	Binary variable for 1996 FAIR Act (1970-1995=0, 1996-2003=1)
11. T	Trend variable capturing technological improvements

The econometric model is based upon autoregressive distributed lags, in which agricultural supply would be a function of expected output and input prices, with expectations formed by parameter weights on lagged output and input price variables; that is, future values are dependent through weights on lagged values. Three-stage least squares are used to estimate the model.

Many factors could be introduced as determinants of demand for corn. Prior research by the Economics Research Service (ERS), a subsidiary of the USDA, on the price determination of corn and wheat provides another basis for the assumptions made in this research. Hoffman and Westcott (2008) created a price determination model for corn and wheat. The authors found the significant factors in the supply of corn to be beginning stocks, imports, and production. In the same manner the significant factors for corn demand are food, seed, and industrial use, feed and residual, and exports. These factors are then broken down into the relevant economic variables to be used in the price determination model.

Hoffman and Westcott recognized the important role that government programs play in the formation of the equilibrium price and quantity of corn. The most significant of these programs was the price support and commodity storage programs. Through price support programs, farmers receive a loan from the government at a designated loan rate per unit of production while raising their crops as collateral. Farmer-owned-reserve programs provided storage subsidies to farmers to store grain under loan for three to five years. Farmers who had grains in this program would not be able to sell their grain unless the price rose above a preset level. The manner in which the model was built and the significant factors developed provides much of the intuition used in the formulation of this research.

Mathew Holt (1992) produced another influential paper on the estimation of corn demand. He used a multimarket bounded price variation model under rational expectations. Price supports were directly incorporated through the market clearing mechanism and price expectations in the supply functions. Holt used restricted reduced-form price equations with conditional expectations. Demand for corn was a function of the price of corn and soybeans, the price of livestock, exports, and a time trend. The supply of corn was a function of expected soybean production, the expectation of the effective producer price of corn,

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seasonal growing conditions, and a binary variable to discount the effects of the 1983 payment-in-kind program and the severe drought.

METHODOLOGY

Using data gathered from the USDA databases, this research will estimate the domestic US demand for corn. All price data are reported in 1983 dollars using the consumer price index published by the Bureau of Labor Statistics. An econometric model will be estimated with two-stage least squares (TSLS).

The TSLS estimation method was chosen due to the fact that a simple multiple regression would fail to capture variations in the regressor that are correlated with the error term. In the supply and demand framework, time series equilibrium points represent movements in both the demand and the supply curves. To isolate the movements in the endogenous variables that are uncorrelated with the error term, a set of instrument or exogenous variables must be used to overcome the identification problem. In essence, we are extrapolating variation of corn demand that, in using ordinary least squares, would otherwise be lost within the error term, out into the open via the use of instrument variables. The use of TSLS in this manner is convenient because it allows for the use of a single estimation procedure, while utilizing information from both the demand and supply curves. By using this method, a clearer picture of corn demand can be had by isolating and using information from both the demand and supply of corn. Below is a brief exposition on the TSLS estimation method following Stock and Watson (2006).

Consider the bivariate linear equation,

$$Y_i = a_1 + b_1 X_i + m_i,\ i=1,\ldots,n, \qquad (3.1)$$

where Y_i is the dependent variable, X_i is the independent variable, and μ_i is the error term representing omitted factors that determine Y_i. If correlation exists between X_i and the error term, ordinary least squares would result in inconsistent estimates of the parameters a_1 and $ß_1$. The instrumental variable method — in this case, TSLS— uses exogenous variable Z_i to isolate that portion of X_i that is uncorrelated with μ_i. The first "stage" decomposes the independent variable X_i into two components, one that is correlated with the regression error μi, and another that is uncorrelated with the error term. This first stage begins with a population regression linking X_i and Z_i:

$$X_i = p_0 + p_1 Z_i + n_i, \qquad (3.2)$$

where p_0 is the intercept, p_1 is the slope, and vi is the error term. This gives the part of X_i, p_0 + p1Z_i, which can be predicted by Z_i. This portion of X_i is uncorrelated with the error term μi in equation 3.1 because Z_i is exogenous. The other component of X_i is vi, which is the portion of X_i that is correlated with the original error μ_i. The first stage of TSLS uses ordinary least squares (OLS) to estimate the parameters p_0 and p_i. The second stage then estimates the dependent variable with OLS,

$$Y_i = f_1 + f_2 X_i + m_i, \qquad (3.3)$$

using the estimated Xi, denoted Xi, and disregarding the error term v_i.

For the purposes of the corn demand model in this research, the instrumental method is used to identify the equilibrium points by using exogenous information to separate the movements in both supply and demand. In the estimation, the log of all variables was used in accordance with general econometric and statistical practices. The following sections discuss the determinants of supply and demand for corn.

3.1 Demand Side

The demand equation to be estimated is given in the following equation, and summarized in Table 3.1.1:

$$lnQ^D_{CN} = a_1 + b_1 lnP^D_{CN} + b_2 lnP_{PLV} + b_3 lnP_{EN} + b_4 lnP_{SC} + m_1 \qquad (3.1.1)$$

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Table 3.1.1 *Corn Demand*

1. Q_{DCN}	Quantity corn produced (millions of bushels)
2. P_{DCN}	Farm-level price of No.2 yellow corn ($/bushel)
3. P_{LVI}	Livestock price index; includes hogs, beef cattle, and poultry
4. P_{EN}	Average rack price of ethanol F.O.B. Omaha, Nebraska ($/gallon)
5. P_{SC}	Price of sugarcane, national average ($/short ton)

The demand for corn is assumed to have three distinct origins: that from livestock producers, ethanol producers and human consumers. According to the ERS Feed Grains Database, of the 10.5 billion bushels of corn utilized domestically in the US during the 2007 market year, more than 55% (5.95 billion bushels) was used as feed for livestock. Cattle feed is comprised of a mix of 11% crude protein mixed with feed grains, typically corn ("Agricultural Alternatives"). The link between livestock markets and the corn market will be represented in the model by the prices of livestock production inputs. Of the corn used to feed livestock in Iowa in 2005/2006, approximately 53% went to hogs, 34% to beef cattle, and 12% to poultry ("Corn Use"). These percentages are used to weight a summation of the prices to create an index (PLVI) that captures the relative effects of each industry's price on the quantity demanded of corn. This price index is hypothesized to show a positive relationship with the price of corn.

According to the ERS Feed Grains Database, in 2007, 3.2 billion bushels, or more than 30% of the corn produced domestically, was used to produce fuel ethanol. This percentage has grown rapidly over the past decade, and was forecasted by the USDA to comprise 20% of corn consumption in the US in the 2006/2007 season, which in fact fell short of the true value (Hoffman et al 2007). Thus it would seem reasonable to assume that if the price of ethanol increases due to increased demand, the price of corn would then increase as the demand for corn increases.

Ferris and Joshi (2004), argue that the production of ethanol should be expected to increase due to a combination of the reduction of MTBE as a blend, federal renewable fuel standards, and tighter restrictions on air quality. And as seen in Tokgoz and Elobeid (2006), ethanol has a complementary relationship with gasoline in the US due to its predominant use as a blend rather than a stand-alone fuel. These observations about ethanol and its relationship with corn support the inclusion of the price of ethanol (P_{EN}) in the demand for corn; as the production of gasoline and refining of oil continues to grow, so will the production of ethanol. The price of ethanol is not determined entirely by the free market, however, because of government policies.

The price of ethanol is in fact subsidized in several ways. The first comes from direct government intervention in domestic ethanol markets. Such intervention occurs in the form of mandated production levels. The Clean Air Act of 1990, for example, mandates a certain level of oxygenated fuel in areas with air quality issues. Ethanol production is also subsidized through tax credits via the Energy Tax Act of 1978, which introduced a $.40 per gallon motor fuel excise tax exemption to ethanol blends of at least 10 percent by volume. Currently, due to several tax laws that have since been adopted, the tax credit per gallon stands at $.51 through 2010 (Elobeid and Tokgoz 2006). The third way in which ethanol prices are subsidized is more indirect. US trade policy on ethanol includes an ad valorem tariff of 2.5 percent in addition to an import duty of $.51 per gallon (Elobeid and Tokgoz 2006). In the following sections, it is important to note that the combination of mandated production, tax credits, and protection from international prices all influence the equilibrium price of ethanol.

The last portion of corn demand in the model is human consumption. This portion includes corn used in the production of high-fructose corn syrup, corn starch, corn sweeteners, cereal or other food products, and beverage alcohol. The amount of corn used in human consumption in 2007 amounted to slightly more than 12% of total corn production (ERS, Feed Grains Database 2008). Sugarcane is a viable substitute for corn as a sweetener in human consumption. For this reason, the price of sugarcane (PSC) is included in the model of corn demand to capture the substitution effect over the years between corn syrup and sugarcane. In fact, according to data from the ERS, the US per-capita use of high-fructose corn syrup has been steadily increasing over the years, indicating that it is a competitor of sugar. The preceding observations concerning sugar would suggest that as the price of sugarcane decreases, sugar would be substituted as a sweetener for high-fructose corn syrup, decreasing the demanded for corn.

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As with ethanol, the price of sugar is hardly a product of free market forces alone. Sugar is one of the most heavily subsidized commodities in the agricultural industry. Sugar markets have been affected by statute since 1789 when the first Congress of the US imposed a tariff on foreign sugar. Acts such as the Sugar Act, also known as the Jones-Costigan Act, solidified government intervention in sugar markets with a series of quotas dictating production (Alvarez and Polopolus 2008). Federal sugar programs in the early 1970s did away with many subsidies to the sugar industry while sugar prices reached record highs. During the mid-1970s, prices once again fell and production costs soared, prompting federal programs to once again introduce price supports and loan programs (Alvarez and Polopolus 2008). Since then, price supports and loan programs have been a consistent part of the sugar industry.

3.2 Supply Side

The supply equation that will support the estimation of corn demand is given in the following equation, and summarized in Table 3.2.1:

$$lnQ^{S}_{CN} = a_2 + g_1 lnP^{S}_{CN} + g_2 lnP_{FTK} + g_3 lnP_{SDK} + g_4 lnP_{CCC} + g_6 lnQ_{CCC} + g_7 lnQ_{HK} + g_8 lnQ_{SE}\, m_2, \qquad (3.2.1)$$

where the equilibrium conditions are assumed to hold:

$$P^{D}_{CN} = P^{S}_{CN}, \qquad (3.2.2)$$
$$Q^{D}_{CN} = Q^{S}_{CN}, \qquad (3.2.3)$$

Table 3.2.1 *Corn Supply*

1. Q^{S}_{CN}	Quantity corn produced (millions of bushels)
2. P^{S}_{CN}	Farm-level price of No.2 yellow corn ($/bushel)
3. P_{FTK}	Fertilizer price index, lagged one year to t-1
4. P_{SDK}	Seed price index, lagged one year to t-1
5. P_{CCC}	CCC total monetary contribution to corn industry ($)
6. Q_{CCC}	CCC total quantity of corn stocks (millions of bushels)
7. Q_{HK}	Area of corn harvested, lagged one year to t-1 (millions of acres)
6. Q_{SE}	Total ending stocks of corn (million of bushels)

In this model, the supply of corn is assumed to be a function of the price of corn, input prices, and the level of government payments. Farm production is inherently dynamic with time lags and expectations dictating current-year production. The harvest in the current year can only be as much as the plantings in the previous year, and thus, many of the production decisions of the farmer take place in the year prior to harvest. Land conversion from one crop to another, or simply expanding a current crop's plantings, is costly. It is for this reason that the quantity harvested in the previous year (Q_{HK}), which implies an area planted, is included in the model of corn supply. The quantity harvested in the previous year captures the switching costs of land in changing crops year over year. Also, farmers can store excess production if prices received are unsatisfactory. Waiting to sell may in turn lead to higher prices received and thus quantity supplied of corn is also a function of year end stocks of corn (Q_{SE}). Quantity supplied of corn is assumed to be a function of the cost of inputs to production. Costs associated with fertilizer and seed total almost 60% of operating costs for farmers in 2006 (ERS, Commodity Costs and Returns 2008). For this reason, and in light of the above stated dynamics, the lagged prices of both of these inputs (P_{FTK}, P_{SDK} respectively) were included in the model of supply.

Government assistance programs have been a part of grain markets since the early 1900s. These programs have changed shapes many times and will change again under the legislation currently in Congress. Today, the structure of agricultural subsidies consists of several different entities: direct payments, marketing loans, countercyclical payments, conservation subsidies, insurance, disaster aid, export subsidies, and agricultural research and statistics (Edwards 2008). There exists no number, variable, or data that fully encompasses all of the changing aspects of each of these payments. As a proxy, to capture the effects of government subsidies on the supply of corn, the reported monetary contribution (P_{CCC}) of the Commodity Credit Corporation (CCC) to feed grain producers and the total quantity of CCC corn stocks (Q_{CCC}) are included in the model.

The CCC is a branch under the USDA Farm Service Agency that is charged with the responsibility of dispersing government funds to farmers. The reported monetary contribution, or PCCC, is an entry within the "Net Budgetary Expenditures" reported by the CCC that presents the "Total support & related." This total includes the value of all deficiency payments, production flexibility contracts, loan deficiency payments, marketing loss payments, diversion payments, disaster payments,

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and storage payments, minus the value of loan repayments, sales proceeds, and other receipts (United States Department of Agriculture 2001). The resulting value, PCCC, is a proxy for the total net governmental value added to the feed grains industry, which includes corn, in the form of subsidies. Quantity of CCC stocks is simply the reported amount of government-owned corn stocks per year. Changes in the CCC's balance sheet gives the amount of government funds being pushed into the corn industry each year and to the amount of corn held off the market by the CCC, which captures the variations in quantity supplied due to changing government holdings.

EMPIRICAL RESULTS

The TSLS estimation method was used to estimate the demand for corn. By transforming the variables via the natural log, coefficient estimates can be read as elasticities. The most important of the elasticities for this research is the cross price elasticity of corn demand with respect to the price of ethanol. Through the estimation of this cross price elasticity, a more thorough understanding of the relationship between ethanol and corn can be realized.

Descriptive statistics of all variables used in the study can be found in Table 4.1.

Table 4.1 *Descriptive Statistics*

	P_{CCC}	PD_{CN}	P_{EN}	P_{FTK}	P_{SC}	P_{SDK}
Mean	6514988.400	3.293	1.920	104.921	40.879	1.159
Median	4969128.800	3.191	1.741	101.175	41.916	1.086
Maximum	1745469800.000	4.938	3.515	141.000	55.465	1.654
Minimum	-787977.600	1.644	1.173	86.100	25.573	0.914
Std. Dev.	4712384.200	0.760	0.556	13.513	8.809	0.210
Skewness	0.834	0.088	1.483	0.914	-0.086	0.962
Kurtosis	2.837	2.868	4.766	3.320	2.047	3.029
Jarque-Bera	2.812	0.048	11.915	3.442	0.938	3.703
Probability	0.245	0.976	0.003	0.179	0.626	0.157
Observations	24	24	24	24	24	24

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Table 4.1** Descriptive Statistics **(continued)

	Q_{CCC}	Q^5_{CN}	P_{LVI}	Q_{HK}	P_{SE}
Mean	181.446	8519.663	181.496	68.720	1896.590
Median	22.350	8921.12	176.176	70.716	1622.313
Maximum	1443.000	11807.086	286.013	75.209	4881.693
Minimum	0.000	4174.251	121.332	51.479	425.942
Std. Dev.	341.534	1779.863	46.734	5.809	1145.530
Skewness	2.531	-0.609	0.655	-1.435	1.344
Kurtosis	9.166	3.329	2.688	4.550	3.901
Jarque-Bera	63.645	1.592	1.814	10.643	8.041
Probability	1.51E-14	0.451	0.404	0.005	0.018
Observations	24	24	24	24	24

The estimation results, shown in Table 4.2, depict statistical significance at conventional confidence levels for some of the variables in the regression. The coefficient of P^D_{CN} is significant and negative as expected, complying with the law of demand. The estimated coefficient of PEN, the price of ethanol, was both positive and significant. Estimation also produced unanticipated results for both the livestock index sugarcane The estimation of the livestock price index, P_{LVI}, was insignificant and negative, a contrary relationship to that developed in the theoretical framework presented in previous sections. Also, the estimated coefficient of the price of sugarcane, P_{SC}, was not significant and positive, denying the claim that sugarcane and corn are substitutes.

Dependent Variables: Log Q^D_{CN}
Method: Two-Stage Least Squares
Sample(adjusted): 1985 2005
Included observations: 21 after adjusting endpoints
Instrument list: Log P_{LVI}, Log P_{EN}, Log P_{SC}, Log P_{FTK}, LogP_{SDK}, LogP_{CCC}

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	8.809551	1.558497	5.652595	0.0000
Log P^D_{CN}	-0.660976	0.274814	-2.405176	0.0286
Log P_{LVI}	-1.136886	0.748165	-1.519567	0.1481
Log P_{EN}	0.800212	0.287237	2.785896	0.0745
Log P_{SC}	1.727418	0.905235	1.908253	0.0745

R-squared	0.663479
Adjusted R-squared	0.579348
S.E. of regression	0.129620
F-statistic	7.396527
Prob(F-statistic)	0.001426

Mean dependent variable	9.062458
S.D. dependent variable	0.199852
Sum squared residual	0.268820
Durbin-Watson stat	1.747423

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One potential cause for the two curious results could be a number of statistical issues. The TSLS estimation method, and indeed any instrumental procedure, is sensitive to the choice of instruments. Conditions for valid instruments are captured in the principles of instrumental relevance and instrument exogeneity:

1. Instrument relevance: corr(Z,X) ≠ 0.

2. Instrument exogeneity: corr(Z,μi) = 0.

That is, the chosen instrumental variables must harbor some relation to the independent variable of concern. Furthermore, the instruments must not be correlated with the error term μi¬. Some of the questionable estimation results may be due to failure of instrumental variables to adhere to these two conditions. For example, the variable QHK, the quantity harvested in the previous year, has a very low correlation with several of the independent variables. The correlation matrix, showing the correlation between all of the variables, is presented in Table 4.3. In addition, there could be instrumental variables not considered in this research that better separate out the portion of Xi that is correlated to the error term.

Table 4.3 *Correlation Matrix*

	Log P_{CCC}	Log P^D_{CN}	Log P_{EN}	Log P_{FTK}	Log P_{LVI}	Log P_{SC}	Log P_{SDK}	Log	Log Q_{HK}	Log Q_{SE}
Log P_{CCC}	1.0000	-0.4075	-0.0377	-0.0200	-0.0200	-0.1829	0.0595	0.2051	0.3565	0.4778
Log P^D_{CN}	-0.4075	1.0000	0.6253	0.5322	0.6981	0.8236	0.5890	-0.7454	-0.0076	-0.8499
Log P_{EN}	-0.0377	0.6253	1.0000	0.7223	0.9094	0.8284	0.8691	-0.7906	0.2746	-0.2226
Log P_{FTK}	0.0337	0.5322	0.7223	1.0000	0.7335	0.7043	0.8241	-0.6600	0.4121	-0.2084
Log P_{LVI}	-0.0200	0.6981	0.9094	0.7335	1.0000	0.9540	0.9279	-0.8674	0.2687	-0.3720
Log P_{SC}	-0.1829	0.8236	0.8284	0.7043	0.9520	1.0000	0.8757	-0.8739	0.2097	-0.5489
Log P_{SDK}	0.0595	0.5890	0.8691	0.8241	0.9279	-0.8626	1.0000	-0.8626	0.4184	-0.2035
Log Q_{CCC}	0.2051	-0.7454	-0.7906	-0.6600	-0.8674	-0.8739	-0.8626	1.0000	-0.2459	0.4260
Log Q_{HK}	0.3565	-0.0076	0.2746	0.4121	0.2687	0.2097	0.4184	-0.2459	1.0000	0.1438
Log Q_{SE}	0.4778	-0.8499	-0.2226	-0.2084	-0.3720	-0.5489	-0.2035	0.4260	0.1438	1.0000

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Another potential reason for the two estimated coefficients being contrary to the theoretical framework is multicollinearity. Kennedy (2003) defines multicollinearity as a phenomenon marked by approximate linear relationships between independent variables. These approximate linear relationships are in fact very common in economic variables. The correlation matrix can be used to detect the presence of multicollinearity and the extent to which it may present difficulties in estimation. Kennedy (2003) explains that multicollinearity becomes an issue of concern when the simply correlation between two independent variables is 0.8 or greater in absolute value. Examining the correlation matrix, several variables show a simple correlation coefficient exceeding the 0.8 benchmark. The most satisfactory way to solve issues of multicollinearity is to include more information, to formalize the relationships among regressors, to specify the relationships between parameters, to remove some variables, to incorporate estimates from other studies, to form a principle component (such as the livestock index), or to use a factor analysis. It is important to keep these potential pitfalls in mind in the ensuing discussion.

As noted previously, the estimated coefficients can be directly interpreted as elasticities. The cross price elasticity of corn demand with respect to ethanol then is 0.80; that is, a 1% change in the price of ethanol creates a 0.8% change, in the same direction, in the demanded for corn. The elasticity of demand for corn, given by the estimated coefficient of PCN, is 0.66. This elasticity of demand is in fact quite reasonable. Shonkwiler and Manddala (1985) found the elasticity of demand for corn to be 0.72, while Taylor and Frohberg (1997) found the elasticity of demand for corn to be 0.50. The elasticity of the supply of corn will be taken from Shonkwiler and Maddala (1985), who found the estimated value to be 0.392. These elasticities are summarized in equation 4.1:

$$e^{S}_{Pcn} = 0.392, \; e^{D}_{Pcn} = 0.66, \; e^{D}_{Pen} = 0.80. \qquad (4.1)$$

To understand how much the price of corn will change due to a change in the price of ethanol, a simple microeconomic relationship found in some principles textbooks (3) will be used (O'Sullivan & Sheffrin, 112). This price-change formula is written as follows:

$$\%\text{ change in equilibrium price} = \frac{\%\text{ change in quantity demanded}}{e^{S} + e^{D}} \qquad (4.2)$$

The numerator captures the rightward shift of the demand curve in percentage terms, counterbalanced by the sum of the elasticity of demand and supply in the denominator. This is reasonable because, if consumers and producers are very responsive to changes in prices, excess demand will be eliminated with a relatively small increase in price. In addition, the percentage change in price will be positive in the case presented because the demand shift is positive. Using the equation 4.2 and the elasticities presented in equation 4.1, a 1% increase in the price of ethanol creates a 0.76% increase in the equilibrium price of corn.

Figure 4.1 Demand Shift Figure

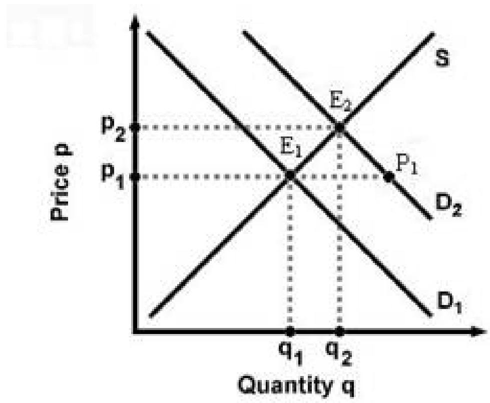

Figure 4.1 shows how the equation captures the 0.76% change represented by the movement from E1 to E2. The movement from E1 to P1 represents the shift in demand of corn from the increase in the price of ethanol. At point P1 there is a shortage of corn which places upward pressure on the price of corn. As the quantity supplied of corn increases to accommodate the increased demand, the price of corn rises from p1 to p2 bringing about equilibrium at point E2. It is the percentage change from p1 to p2 that is then given by equation 4.2.

This equation can be used to examine current trends in ethanol production and what effects this might have on the equilibrium price of corn. During the period 2000 through 2007, the price of ethanol increased by an average of 13.18% per year, which at the 2007 price of ethanol represents a $.30 change. Using this average price increase and the estimated cross price elasticity of demand for corn with respect to ethanol, a 10.544% increase in the demand for corn is obtained; at 2007 corn production levels, this increase represents nearly 1.4 billion additional bushels. Then using equation 4.2, a 13.18% increase in the price of ethanol will increase

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the equilibrium price of corn by 10.023%. Using the February 2008 price of corn, $4.25 per bushel, a 10.023% increase as a result of the average yearly increase in the price of ethanol increases corn prices by $.43.

The conclusions to be drawn from these empirical results follow directly from the established relationships between corn and ethanol. The estimated demand function for corn, coupled with the price change formula, suggest that an increase in the price of ethanol will increase the equilibrium price of corn as the markets adjust. Costs of corn production, on the other hand, have grown at a low and stable rate over the past decade. The total costs of production in the corn industry, including inputs, taxes, and opportunity costs, have grown an average of 2% over the past decade (ERS, Commodity Costs and Returns 2008). The conclusion then follows that with the likely trends in ethanol markets leading to increased ethanol prices and thus increased corn prices, and with the cost structure of farmers remaining stable, subsidies for corn production are unwarranted. Assuming the growth rate of costs remains constant, the increase in the price of corn represents an increase in the profitability of the corn industry. Intuitively, increasing profitability is not a sign of a struggling industry in need of a transfer of wealth from taxpayers to firms.

Agricultural subsidies are meant to control prices and stabilize farming income. As ethanol is forced upon refiners as a blending agent to address environmental concerns, corn farmers' income will stabilize itself through market mechanisms. The theoretical rationale behind the general form of subsidies is to capture some sort of social benefit or loss that is not manifested in the private sector's cost-benefit structure. If nothing else, the effects of ethanol on corn markets would at the very least decrease the need for subsidies in the short run, thereby allowing the market mechanism to dictate the most beneficial use of resources. The reallocation of crops resulting from the increase in demand for corn will take time. Once the new equilibrium price is reached, the adjustment of input markets could lead to increase costs, thus returning corn farmer profitability to its original state. In this way subsidies in the long run may be justified, given an agenda of price and quantity control.

As stated above, some of the endogenous variables returned questionable relationships to the quantity of corn. These problematic relationships may be a sign of inadequate instrumental variables. Estimation errors may also contribute to the existence of multicollinearity. Additional information could be added to the model to decrease the effects of said statistical issues. One such piece of information could be a variable that fully captures the opportunity cost of farmland. A farmer who grows corn may switch to some other commodity if doing so would maximize profits. This underlying opportunity cost of farmland may include a copious amount of other crops that could potentially grow on the land. The number and type of substitute crops then would depend on the geographical region. Mapping these opportunity costs across farms may be the subject of further research.

CONCLUSION

The research presented addresses three interdependent topics, namely, agricultural subsidies, the ethanol market, and the corn market. A model for corn demand was estimated using a TSLS instrumental variable method yielding the elasticity of demand for corn as well as the cross price elasticity of corn with respect to ethanol. These estimates were then used in unison with a previous study's estimated elasticity of supply for corn to show the effect a given percent increase in the price of ethanol has on the equilibrium price of corn.

The importance of each conclusion made in this study is self-evident. Subsidies are ideally used to facilitate some social benefit existing beyond the private cost-benefit structure. This benefit would otherwise go unutilized if not for government intervention. Governmental support of such goods then brings about a more efficient or optimal outcome. In order to better understand whether these billions of tax dollars poured into the corn industry every year represent economic waste, a better understanding of the social benefits of corn production must be achieved. The burden of proof, demonstrating some social benefit in the production of corn, must then be satisfied before government legislation manipulates corn markets. If there exists some social benefit to corn production, subsidization of the corn industry may well be justified. However, if private production is correctly aligned with the theoretical social costs and benefits of corn production, agricultural subsidies necessarily lead to an inefficient outcome, transferring wealth from taxpayers to corn producers.

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FOOTNOTES

1. The Organization for Economic and Co-Operation and Development in Paris, France brings together the governments of countries committed to democracy and the market economy from around the world to support and propagate economic growth.

2. Since the paper (Ferris and Joshi 2004) was written in 2004, ethanol production has far surpassed their predictions and has in fact reached over 4,800 million gallons in 2006, reaching 14.3% of total US corn supply. For more information see Iowa Corn Growers Association <http://www.iowacorn.org/cornuse/cornuse_3.html> (Accessed 25 Nov. 2007).

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